Institute of Experimental Physics
Slovak Academy of Sciences, Košice
1969-2019




Premises, 9 Park Angelinum, Košice

Main Building, 47 Watsonova Street, Košice

Premises, 2-6 Bulharská Street, Košice

Branch location on Lomnický Peak

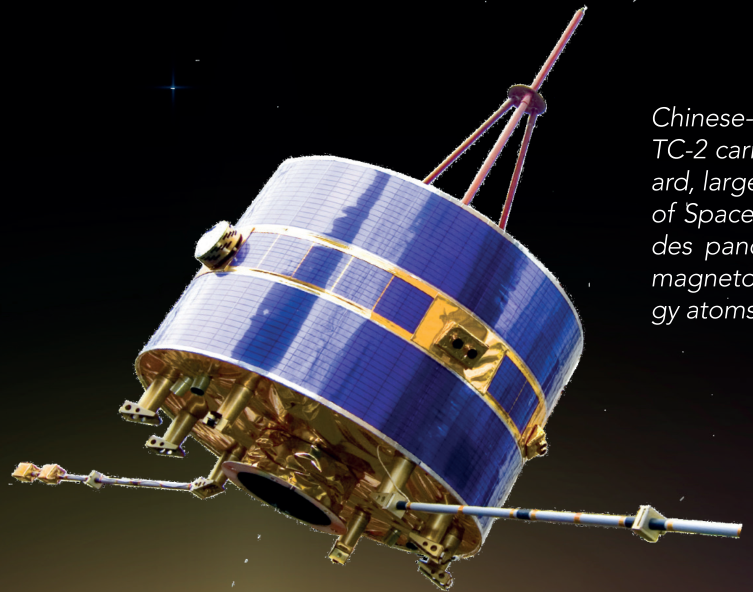
Introduction

The Institute of Experimental Physics of the Slovak Academy of Sciences (IEP SAS) in Košice was established by the SAS Presidium on January 1st, 1969. The Institute, which has since grown considerably, was originally a branch office of the Institute of Physics, SAS, Bratislava. The latter was founded in Košice in 1964 with a focus on the physical sciences in the fields of cosmic radiation, ferromagnetism and high energy physics. Prof. Juraj Dubinský became the first director of the Institute and held this office until 1979. Between 1980 and 1985 the Institute was headed by Prof. Vladimír Hajko, from 1986 till 1990 by Dr. Michal Seman, from 1991 till 2007 by Dr. Peter Kopčanský, from 2007 till 2015 by Dr. Karol Flachbart and from 2015 till 2019 again by Dr. Peter Kopčanský. Since August 1st, 2019 the position of director has been filled by Dr. Zuzana Gažová.
The present research activities of the Institute cover basic research in several fields of modern physics (condensed matter, subnuclear and space physics and biophysics) and integrates interdisciplinary areas of chemistry, biology and nanosciences with nanotechnologies. The current organization of the Institute constitutes of 10 research departments:

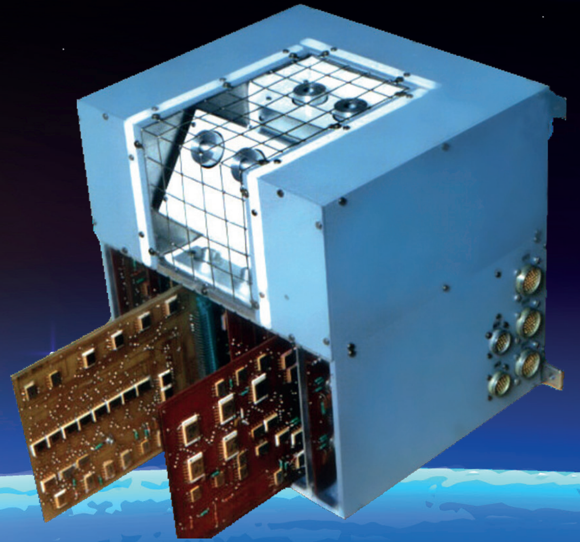
- Department of Space Physics
- Department of Subnuclear Physics
- Department of Magnetism
- Centre of Low Temperature Physics
- Department of Metal Physics
- Department of Biophysics
- Department of Theoretical Physics
- Department of Experimental Chemical Physics
- Department of Materials Physics
- Department of Applied Magnetism and Nanomaterials

Currently the Institute employs about 150 people, more than half being research scientists, and 16 post-graduate students. Its main premises are located at 47 Watsonova Street, Košice. The Centre of Low Temperature Physics operates and shares research laboratories with the Institute of Physics, Faculty of Science, P.J. Šafárik University. The Departments of Biophysics and Space Physics are located separately in the reconstructed premises at 2-6 Bulharská Street, where the Operational Workshops of the Institute are located as well.
The accreditation of the SAS Institutes ranks the IEP among the top workplaces within SAS. The Institute maintains a highly respectable position at both the national and international level with a well established experimental infrastructure. Several of the experimental devices constructed at the Institute are unique. For example, the Institute is one of the few physics workplaces with a capability to achieve very low temperatures (a thousandth of a degree above absolute zero, –273,15 °C), thus allowing the study of materials under extreme conditions. A wide range of condensed matter physics and its potential applications are under investigation, including high-temperature superconductivity, magnetic fluids, amorphous metal systems or micro- and nanocrystalline materials. Scientific equipments developed at the Institute have been successfully deployed on orbital satellites and have been invaluable tools contributing to our knowledge of the physical properties of interplanetary space. Furthermore, the Institute has a keen interest in research of the fine structure of matter, with our investigators utilizing the giant particle accelerators in facilities such as FERMILAB in Batavia, USA or CERN in Geneva, Switzerland. In addition, the research programs are dealing with the problems of contemporary biophysics and chemical physics as well.
During fifty years of its existence IEP SAS has developed fruitful foreign cooperation with contacts in all of the developed countries of the world. Within Slovakia, members of the institute intensively collaborate with Pavol Jozef Šafárik University and the Technical University in Košice, as well as with several institutes of both Sections I (Physical, Space, Earth, and Engineering Sciences) and II (Life, Chemical, Medical, and Environmental Sciences) of the Slovak Academy of Sciences.
The Institute sponsors doctoral studies in cooperation with the Faculty of Science, P.J. Šafárik University in four fields of study: 1) Physics of condensed matter; 2) General and mathematical physics; 3) Biophysics and 4) Progressive materials. In cooperation with the Faculty of Electrical Engineering and Informatics in Physical engineering of advanced materials and in cooperation with the Faculty of Materials, Metallurgy and Recycling in the study field Materials.
In the following text the departments present selected topics of their research programs.

Department of Space Physics



Chinese-European satellite Double Star TC-2 carries the NUADU detector on board, largely developed at the Department of Space Physics IEP. The detector provides panoramic snapshots of the Earth´s magnetosphere by means of neutral-energy atoms.



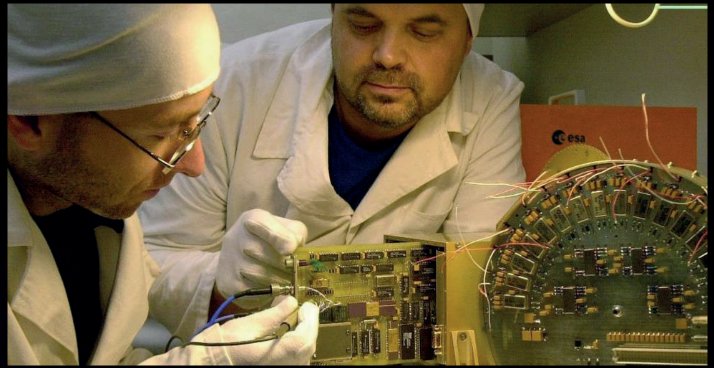
Spectrometer of cosmic energetic particles DOK-2, developed at the Department of Space Physics IEP, has provided a wealth of valuable data on the Earth´s magnetosphere.

Energetic particle spectrometer MEP-2. The configuration on delivery and after installation on board of the space observatory Spektr-R (Radioastron).

Contribution to mission ESA – Rosetta. The first landing on comet.

Research focuses on the physical processes that take place under extreme conditions found in space that typically cannot be observed under laboratory conditions. Our goal is to gain novel information on cosmic energy particles including cosmic radiation. This is accomplished via the analysis of ground and satellite measurements, personal observations, simulation of physical processes in the Earth's heliosphere and magnetosphere, and preparation of new cosmic experiments.
The Department has participated in development and implementation of key components of experimental equipment placed on ~30 satellites, space probes and high altitude rockets. Ground measurements are continuously collected from a neutron monitor at Lomnický Peak, with real-time data available at http://neutronmonitor.ta3.sk. For further information about the Department see http://space.saske.sk.

Development of the Electrical Service System.



Preparation of the NUADU detector.

Main fields of research

- Variations in the low-energy component of space radiation and effects of processes in the Earth's heliosphere and magnetosphere
- Acceleration, transport and losses of medium-energy particles (between solar wind and space radiation) in the Earth´s magnetosphere and near its border areas
- Links between cosmic energy particles and cosmic weather
- Participation in JEM-EUSO program devoted to scientific research of cosmic rays of highest energies
- Airglow production in the upper layer of the atmosphere

Department of Subnuclear Physics

The Department focuses on research of the structure of elementary particles and nuclear matter in ambitious experimental projects conducted by the world´s largest accelerator centres such as the Joint Institute for Nuclear Research in Dubna near Moscow, the Deutsches Elektronen Synchrotron Institute in Hamburg, Fermilab in Batavia USA and CERN in Geneva, which is currently our main partner. At present two main research topics drive the Department, namely the study of hard processes in proton-proton collisions and exploration of nuclear matter characteristics under extreme conditions.

Higgs boson
The picture below displays a contemporary view of the structure of the matter. This picture outlines our present knowledge the micro-structure of our world. As you can see we distinguish three quarks and leptons families, the four force carriers (we have not yet observed the gravitino, the carrier of the gravity). In the centre of the picture is Higgs boson - this position reflects its very important role - interactions of this boson determines all basic properties of the "matter" particles, that is the quarks and leptons.

Up to year 2011, the Higgs boson was known only as a theoretical prediction. The **ATLAS** and **CMS** experiments at CERN announced its experimental discovery in the summer of 2012.

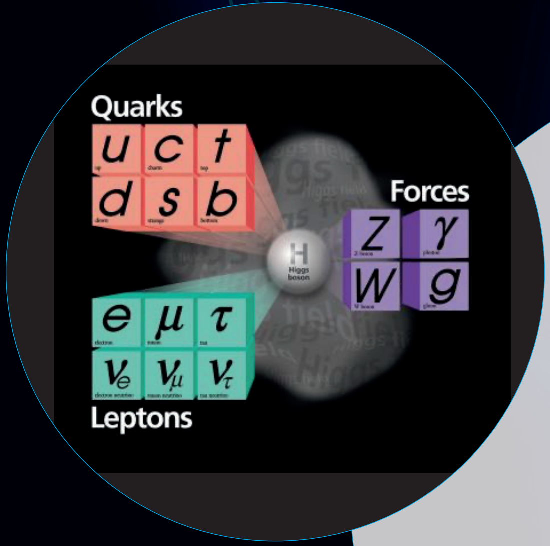
The Department of Subnuclear Physics actively participated in this most significant discovery in high-energy physics in the last 30-years. We are the founding institute - we became a member in the ATLAS collaboration starting from 1994. The ATLAS experiment today is a collaboration of 237 institutes from 38 countries.

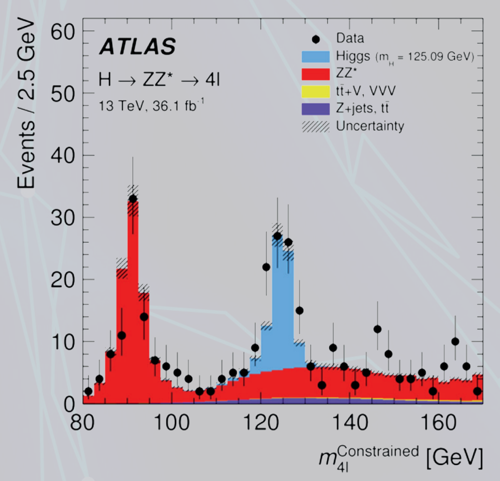
Our responsibilities are closely connected with the Liquid Argon calorimetry (Lar), which measures energies of the electromagnetically interacting particles. We are responsible for the on-line detector calibration and monitoring, as well as for part of the reconstruction software.
In the graph it is possible to see the candidate of the Higgs boson production from the decay of muon and electron pairs. Here the invariant mass shows the Higgs mass 123.9 GeV. The next figure shows present histogram of the Higgs production measured in the decay channel H -> 4 charged leptons.

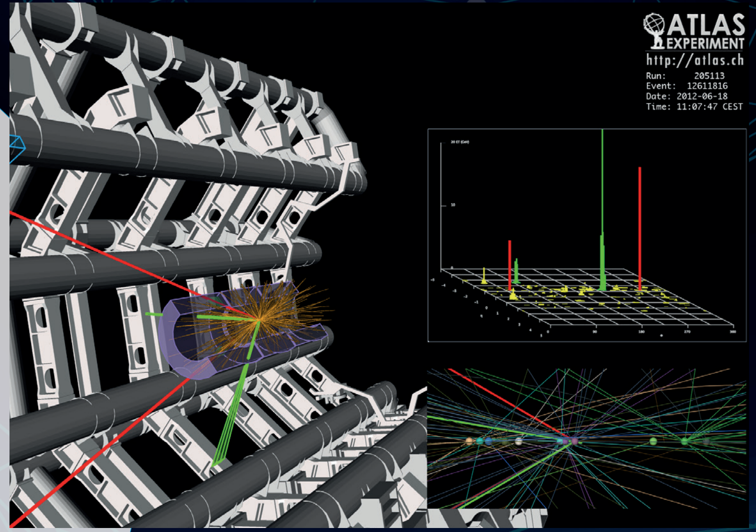
After the second long shutdown (2019-2020) the ATLAS experiment will resume its operations in 2021. One of the main goals will be continuation of investigation of Higgs boson properties at 300-time higher luminosity of the LHC collider. This step will open a study of the so-called full Higgs sector.

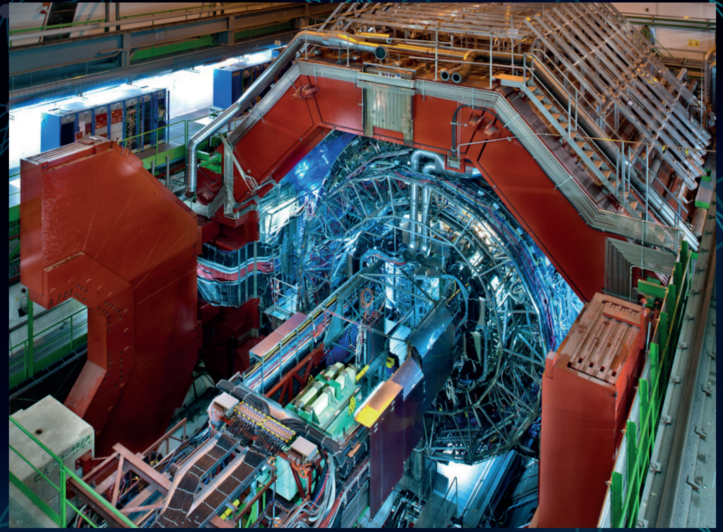
Exploration of the new state of nuclear matter
Protons and neutrons consist of quarks held together by the strong force known as the strong interaction. Its source lies in the mutual interchange of particles called gluons. No isolated quark or gluon has been observed so far – they are confined within composite particles such as protons and neutrons.
A contemporary theory of the strong interaction predicts the "liberation" of quarks and gluons at temperatures exceeding 2000 billion K and the transformation of nuclear matter into the **quark-gluon plasma** state. Such extreme conditions existed in nature for a few millionths of a second after the Big Bang. The collision of two lead nuclei accelerated in the LHC collider close to the speed of light will enable us to gain a speck of this hot matter with size of an atomic nucleus, and to observe how it undergoes through the process of expansion and cooling into the state of normal matter. By studying such collisions at the LHC, the **ALICE** experiment will allow us to peer deep into the processes evoked by the strong interaction and glimpse matter the way it was possible only immediately after the Big Bang. Our participation in the ALICE experiment is the continuation of twenty years of cooperation with CERN on the heavy ion experiments, which was our contribution to the official CERN announcement of a new state of matter with quark-gluon plasma characteristics in 2000.

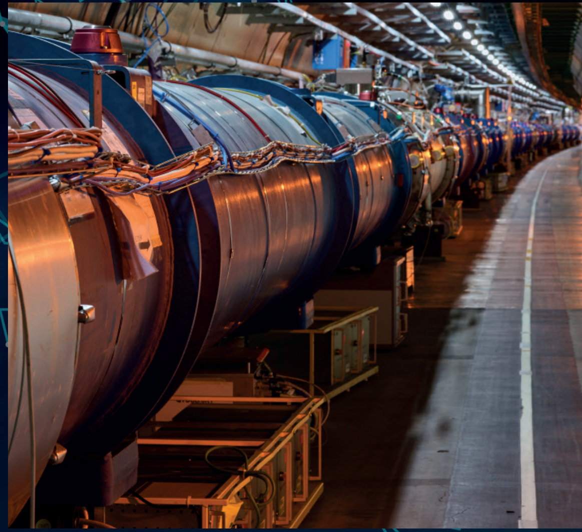
Physics results obtained by the ALICE experiment gave us deeper look into the heart of hot and dense nuclear matter - be it the measurement of the highest temperature in the known Universe, precise measurements of mass differences between light nuclei and antinuclei and lots of new information about the evolution of the quark-gluon plasma.



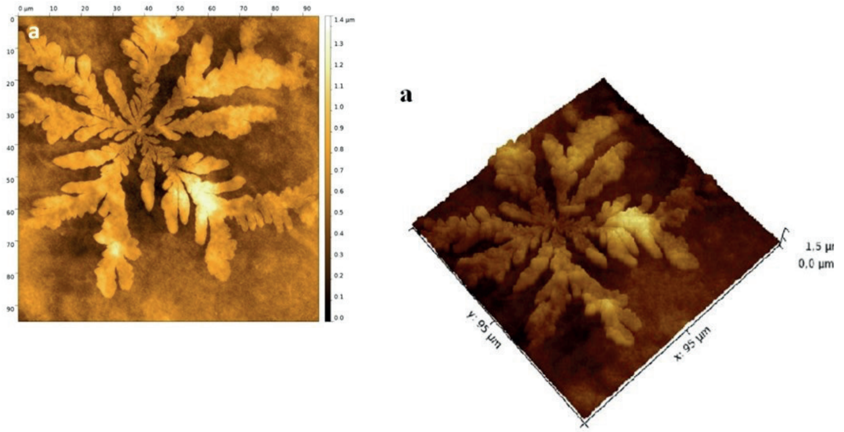








The original form of this Department was established as early as 1964 within the branch office of the Institute of Physics, SAS, Bratislava in Košice. In 1969, when the Institute of Experimental Physics was established, the magnetism group became an autonomous Department. Today, 4 main research streams are handled within the Department: magnetic fluids, molecular magnets, intermetallic materials, and

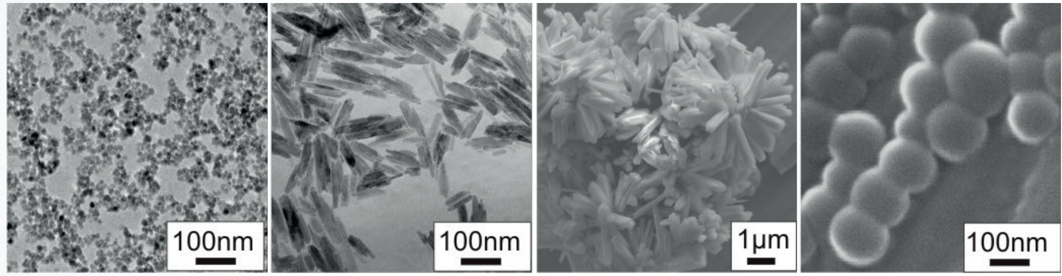


electron transport and tunneling spectroscopy. In these fields the Department has won awards for its scientific results in Slovakia and abroad. Furthermore, within the framework of bilateral and multilateral projects (projects 5RP, 6RP and 7RP), we have established broad international collaborations with several prominent institutes including GHMFL and CRETA CNRS Grenoble; IFM PAN Poznan; Institute for Solid State Physics and Optics, Wigner Research Centre for Physics Budapest, Hungary; Polytechnic University of Timisoara, Romania; A. Mickiewicz University of Poznan; Jean Monnet University, St. Etienne; Charles University, Prague; Institute of Physics, Academy of Sciences, Czech Republic; Institute of Physics, Academia Sinica, Taiwan; JINR Dubna, Russia; DESY, Hamburg, Germany; Institute of Chemistry, Military University of Technology, Warsaw, Poland; Institut fur Katalyseforschung und technologie, Karlsruher Institut fur Technologie (KIT), Postfach, Karlsruhe, Germany; National Chiao Tung University, Tainan City, Taiwan.

Magnetic fluids

Today the Department is capable of preparing magnetic fluids based on various basic liquids (e.g. water, kerosene, mineral oil, wax) with magnetite as a magnetic moment carrier. Besides the preparation of magnetic particles of various shapes and parameters (5-300 nm) the Department also studies basic physical properties, aggregation processes of magnetic particles, magneto-optical and magneto-dielectric properties of magnetic fluids and their composite systems with liquid crystals. The properties of magnetic fluids can be easily influenced by external magnetic fields and thus are widely applicable in industrial practice as well as biomedicine, especially for the targeted transport of drugs in cancer treatment, cardiovascular disease treatment and radiodiagnostics. For the results the team achieved, it was given an SAS award for significant contribution to international cooperation and was conferred the right to organize the International Conference on Magnetic Fluids ICMF 11 in Košice in 2007.

Molecular magnets



The properties of rare-earth ferricyanides have been intensively investigated in the field of molecular magnetism. Detailed knowledge of the crystal structure of these materials can significantly contribute to the understanding of physical processes and phenomena taking place within them, their interpretation in the field of basic research, but also to optimization of the utility properties of prepared materials for their applications.

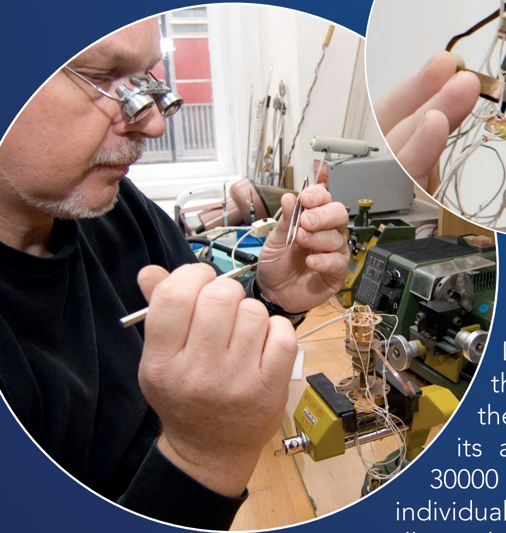
Intermetallic compounds

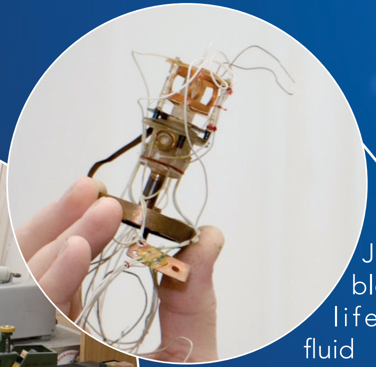
Research in the field of intermetallic compounds focuses mainly on the study of cooperative phenomena and strong electron correlations in selected systems comprising 4f- and 5f- components, aiming to contribute to the understanding of phenomena such as heavy fermion behavior, Kondo grids, spin fluctuations and far-reaching magnetic configurations through the study of structure, magnetic, thermal and transport properties in compounds of d- metals and f-metals.

Electron transport and tunneling spectroscopy

This group concentrates mainly on the experimental study of selected strongly-correlated electron systems characterized by anomalous transport properties associated with metal-insulator transition, heavy fermion superconductivity or colossal magnetoresistance. One of the group´s most significant areas of interest involves the development and implementation of a new experimental method – tunneling calorimetry – enabling the exact determination of the heat generated in individual tunnel electrodes. The results of a systematic study indicate that generated heat represents the energy of quasi-particles originating from inelastic processes accompanying the process of elastic tunneling.

Centre of Low-Temperature Physics





Construction of chamber for superfluid ^3He

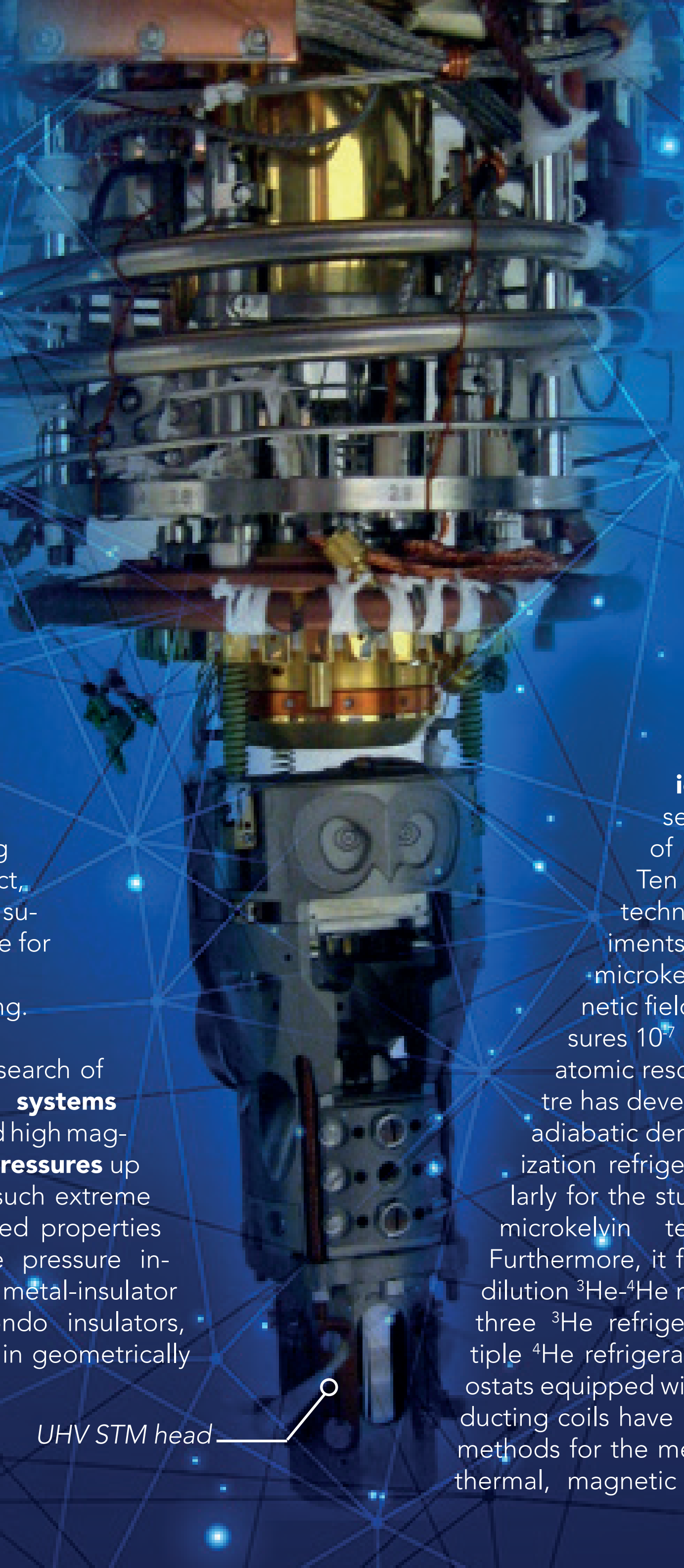
Just as blood is a life-giving fluid for our body, **liquid helium** is important for experiments at **very low temperatures**. Liquid helium is obtained by the liquefier which is part of the Centre´s infrastructure, and its annual production is about 30000 litres. This is distributed to individual laboratories of the Centre as well as to laboratories at P.J. Šafárik University or Technical University in Košice, where it serves for cooling the magnets in magnetic resonance tomographs. These are magnets made from superconductors.

Superconductors have been intensively studied by various laboratory methods (point contact spectroscopy, AC calorimetry, scanning tunneling microscopy – STM). Probably the most significant result was achieved in the study of superconducting **MgB_2**, where as a first laboratory we have managed to spectroscopically detect two superconducting gaps. MgB_2 has been quickly adopted for use in superconducting magnets thanks to its comparatively high critical temperature and magnetic field values.

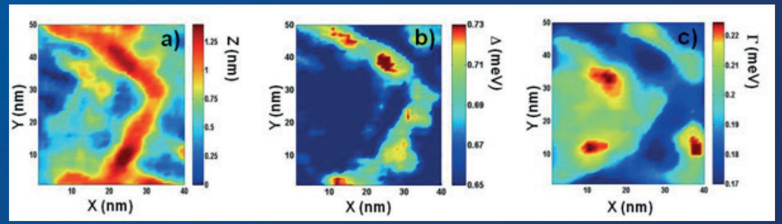
Production of liquid ^4He in liquefier CTi 1410

Having **ultra-low temperatures well below 1 mK**, the Centre has a unique capability to cool the rare isotope of ^3He into its very complex superfluid state, and use this **superfluid** state as the model system simulating various exotic (cosmological) phenomena. Among these phenomena are, for example, the quantum turbulence, the quantum fluctuation of the physical vacuum, the Majorana excitations, the cosmological effects like the black/white hole event horizon, the Hawking radiation and the Unruh effect, etc. The last but not least the superfluid ^3He also provides a base for modelling of quantum bits - **Q bits** and quantum computing.

The Centre concentrates on research of **strongly correlated electron systems** not only at low temperatures and high magnetic fields but also at **high pressures** up to about 10 GPa. Under such extreme conditions the unexpected properties could be observed, like pressure induced superconductivity, metal-insulator transition in topological Kondo insulators, supersolid or skyrmion phases in geometrically frustrated antiferromagnets. Most recently the Centre focuses on the study of **materials with reduced-dimensions**. All this research cannot go on without cooperation with world's top laboratories (especially HZB and BESSY Berlin, WMI Garching, CEA and CNRS Grenoble, Univ. Lancaster, Madrid, Paris, Helsinki, GPI Moscow, TU Vienna, NIMS Tsukuba, etc.).

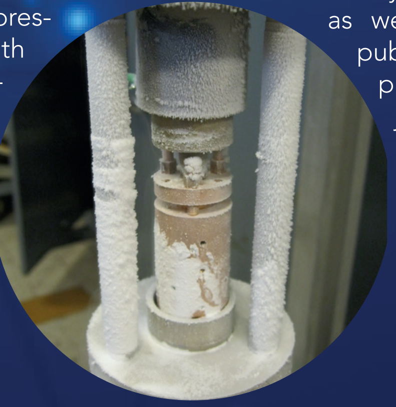


UHV STM head



Correlation studies of the surface topography structure of MoC ultrathin films a) with the locally measured superconducting energy gap b) and pair-breaking parameter c) measured with Low Temperature STM system at 450 miliKelvin

Centre of low temperature physics in Košice is an exceptional research complex, since 2009 member of the European Microkelvin Platform. Ten researchers with the support of three technicians are capable to perform experiments in the temperature range from 100 microkelvin up to 400 K, in magnetic fields up to 12 T, at pressures $10^{-7} \div 10^{10}$ Pa and with atomic resolution. The Centre has developed a custom adiabatic demagnetization refrigerator particularly for the study of ^3He at microkelvin temperatures. Furthermore, it features four dilution ^3He-^4He refrigerators, three ^3He refrigerators, multiple ^4He refrigerators. All cryostats equipped with superconducting coils have implemented methods for the measurement of thermal, magnetic and transport properties, NMR, EPR, STM and point contact spectroscopy, mostly developed in the Centre. Commercial facilities for ultra-high vacuum sample treatment and STM measurements (SPECS UHV STM), scanning Hall-probe microscopy (SHPM Attocube) and basic physical properties measurements with Quantum Design PPMS and MPMS systems are available as well. The research is published in the most prestigious scientific journals as those belonging to the Nature Index and presented at major conferences. The laboratory provides an open access to its unique infrastructure and offers expertise in vacuum and cryogenic techniques to industry.



Diamond Anvil Cell loaded by liquid argon for generation of hydrostatic pressure 10 GPa

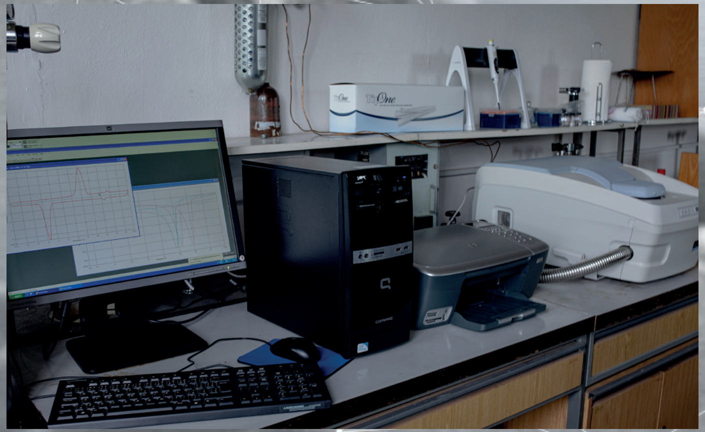
Nuclear stage of ^3He-^4He dilution refrigerator can be cooled down to almost absolute zero temperature
The coldest place in Central Europe

Department of Metal Physics

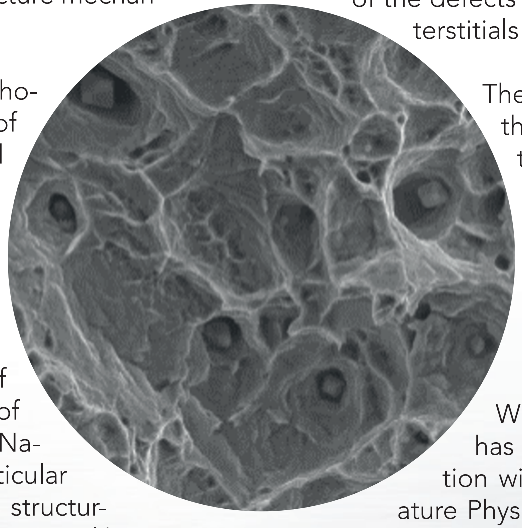
The Department´s research activities focus on the linkage between the structures and properties of metallic materials. Metastable amorphous metallic materials, typically prepared by rapid cooling of the hot melt, were discovered in the 1960s. Since then they have progressively become the subject of intense interest for physicists, technologists, development and construction workers. Currently the Department´s main research area is the study of mechanical properties, plastic and inelastic deformation, fracturing processes and stability of amorphous metallic materials prepared by rapid cooling. The methods of fractographic analysis and quantitative statistical fractography are used in the study of fracture surfaces in amorphous metals, the shape of thin ribbons and bulk alloys breaking at a wide range of temperatures, and deformation speed under various types of straining. The processes of formation and extension of unstable fission in amorphous metal structure are investigated by mechanical testing of amorphous metallic materials at temperatures above 4.2 K and by the application of linear fracture mechanics methods.

TGDTA SETARAM SETSYS 16 analyser

VEGA3 LMU scanning electron microscope



DSC8000 differential scanning calorimeter



The Department also studies the homogeneous plastic deformation of amorphous metal structure and properties of deformation defects by watching the processes of inelastic deformation and flowing under the influence of mechanical pressure, and by analyzing these processes using numerical methods presu¬ming the existence of an activation energy spectrum of thermally-activated processes. Nanocrystalline materials form a particular group of metallic materials with structural states considerably distant from equilibrium state. The Department studies fracture regularities in these materials. Their structu-ral stability is explored using thermal analysis methods.

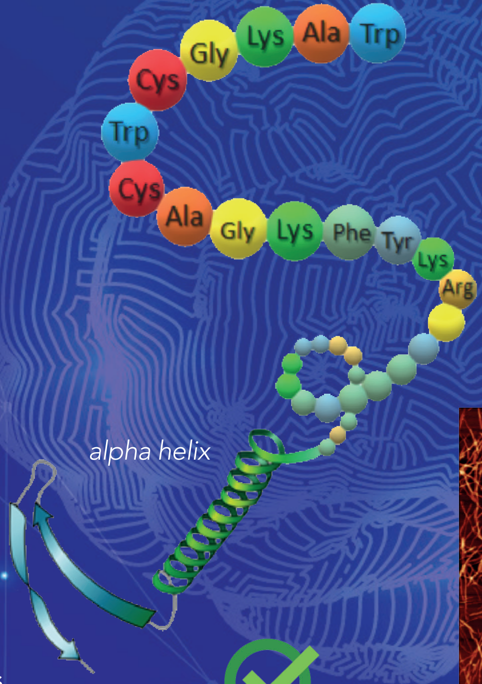
In the last decade, the department has also devoted itself to the description of deformation and failure of nanocrystalline and high entropic alloys after intensive plastic deformation. Some peculiarities of structural relaxation and temperature changes of mechanical properties of metallic glasses are interpreted based on the assumption of similarity of the defects in metallic glasses with model defects - interstitials in the crystal lattice.

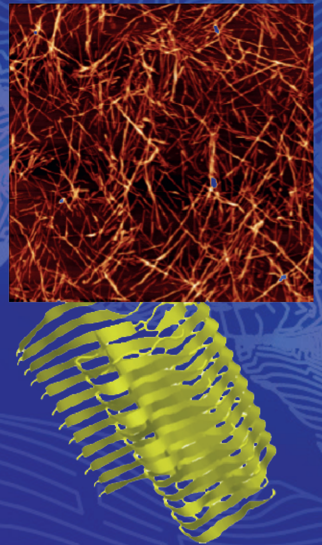
The influence of the geometric conditions on the discontinuous plastic deformation during the nanoindentation on the final morphology of the deformed region is investigated for different types of metallic glasses. The phase transitions are also studied in the model chalcogenide glasses and in the different composites with the magnetic nanoparticles.

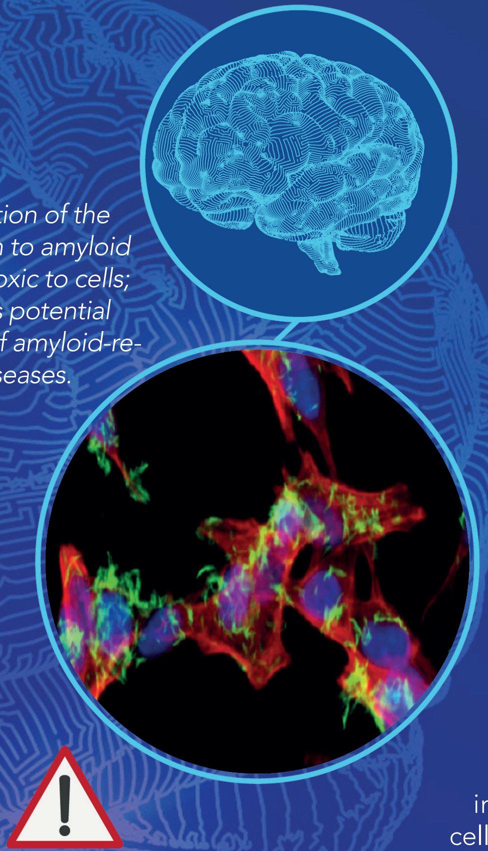
Within the research frame, the Department has developed active and long-term cooperation with the B. Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences of Ukraine, Kharkov (Ukraine); Voronezh State Technical University (Russian Federation) and the University of Groningen (Netherlands).

Department of Biophysics

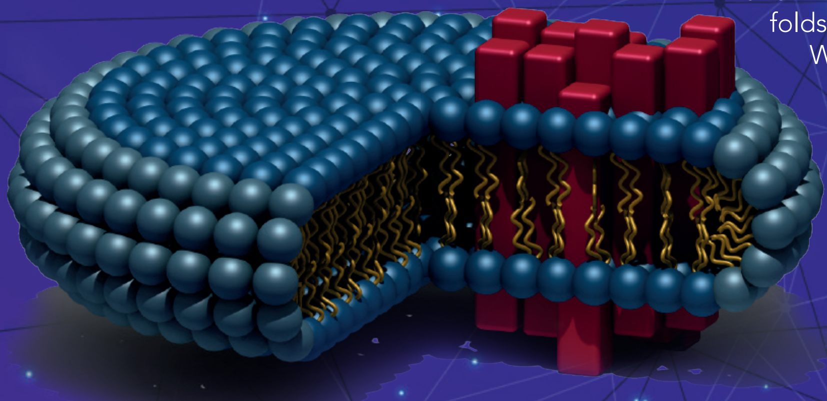
Protein Amyloid Structures
Proteins consist of the chain of amino acids arranged into native 3D structure which allows them to perform their function. The formation of non-native protein structures can lead to the formation of amyloid fibrillar aggregates with a typical highly organized structure called cross – β motif. The presence of amyloid structures is the hallmark of more than 50 progressive and incurable amyloid disorders like Alzheimer's and Parkinson's diseases or type II diabetes. Recently it was determined that amyloid structures can carry out also physiological functions, such as the formation of bacteria biofilm providing them protection and resistance or biosynthesis of several important proteins in the human body.
Mechanism - the research is focused on a fundamental understanding of molecular processes underlying the formation of non-native conformers of poly/peptides and their tendency to form morphologically different amyloid aggregates.
Amyloids in Diseases - understanding of amyloid's role in the pathology of various amyloid diseases and determination of the cytotoxic amyloid structures is important for the identification of new inhibitors of amyloid aggregation among small molecules and nanoparticles. The team is implementing innovative multi-target-directed-ligands strategy to develop new drug candidates against multifactorial **Alzheimer's disease.**
Amyloid Nanobiomaterials - amyloids can be used for preparation of nanobiomaterials (e.g. nanowires, nanolayers, gels, scaffolds, templates, and liquid crystals). We are interested in search of conditions leading to formation of amyloid based nanomaterials with controlled properties.







Transformation of the native protein to amyloid aggregates toxic to cells; inhibitors as potential therapeutics of amyloid-related diseases.



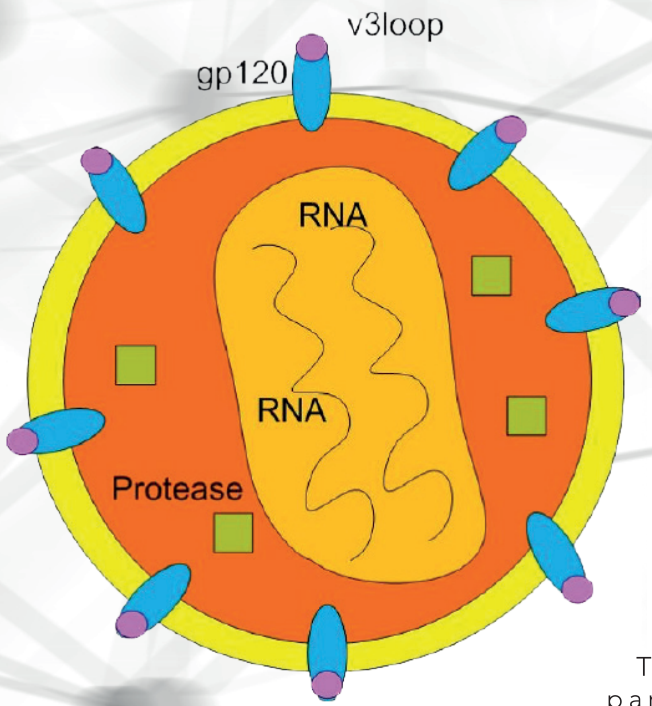
Schematic model of incorporation of protein (cytochrome c oxidase) into membrane model system (bicelle)

From biomacromolecules to supramolecular complexes: structure, stability, and reactivity - experimental and theoretical studies
Another area of research is focused on medically important biomolecules, proteins, and phospholipids that can be irreversibly modified or damaged under normal or pathological cell's conditions. In particular, we are interested in the study of mechanisms of oxidative damage of individual cell components by oxidative stress. It is well-known that the overproduction of reactive oxygen species leads to impairment of normal cell function, such as decreased activity and intracellular communication, which are mediated by protein interactions. Oxidative stress-induced modification of biomacromolecules is believed to initiate or contribute to many pathological conditions including neurodegenerative diseases, ischemia/reperfusion injury, atherosclerosis, and overall aging. Our main goal is to identify the structural and functional consequences of oxidative stress at the molecular level. In this context, the role of hydrophobic and hydrogen bond interactions appears to be particularly important. We are engaged in experimental and theoretical studies of protein interactions with phospholipids, phospholipid membranes and model systems (detergent micelles, liposomes, bicells, nanodiscs, and others). The structures and function of the studied molecules are analyzed by complex biophysical and biochemical methods. Understanding structures/functions of the studied molecules and their mutual interactions help us to manipulate with them to affect their biological activities so that they can be used for diagnostics of diseases, as drugs or as advanced materials. A theoretical study, including mathematical modeling, can significantly help not only in the interpretation of experimental results but also in the selection of effective chemical compounds for further experimental work.

Computer analysis of biomedical images and micro-biorobotics
Image analysis and micro-robotics' group is mainly oriented to "lab-on-chip" applications exploiting optical tweezers, which manipulates with microstructures by laser traps. Various elastic (deformable) microstructures prepared by two-photon polymerization are exploited in viscosity measurement and single-cell manipulation. The automation of the micromanipulation process leads to a micro-robotic research area aiming to improve the biophysical experiments. Another area of interest of this group is the application of image analysis methods in microscopy.

Various polymerized structures driven by laser traps. a) fork-like, b) elastic, c) rotating

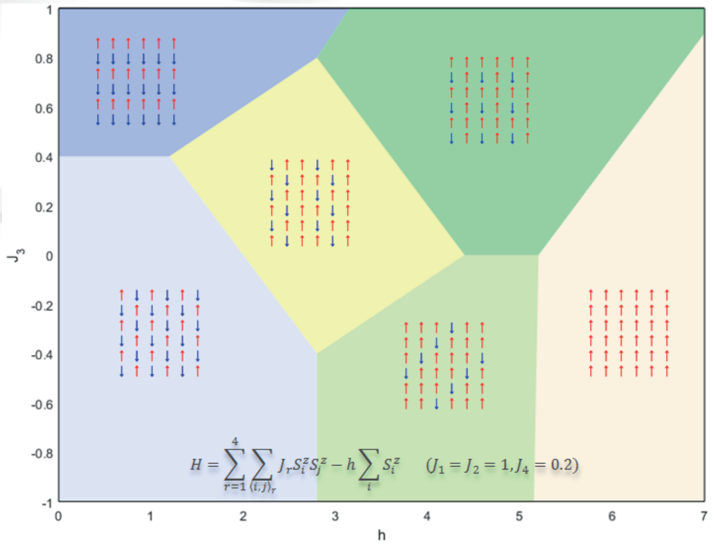
Department of Theoretical Physics



The Department of Theoretical Physics has multidisciplinary character and specializes in a wide range of physics problems such as condensed matter physics, stochastic processes like turbulence, particle physics, as well as interdisciplinary studies.

Condensed matter physics

Our interests in the condensed matter area are focused on a description of various cooperative phenomena that result from electron-electron, spin-spin and electron-spin interactions. In particular, there are valence and metal-insulator transitions, formation of charge and spin ordering, itinerant magnetism, enhanced magnetocaloric effect, electronic ferroelectricity, superfluidity and superconductivity, to mention only a few. For description of these phenomena we use various generalizations of the classical as well as quantum Hamiltonians (Ising model, Heisenberg model, Falicov-Kimball Hubbard model) on standard as well as special lattices (Shastry-Sutherland lattice, Husimi lattice) and for their solution we use primary the exact analytical as well as exact numerical methods.



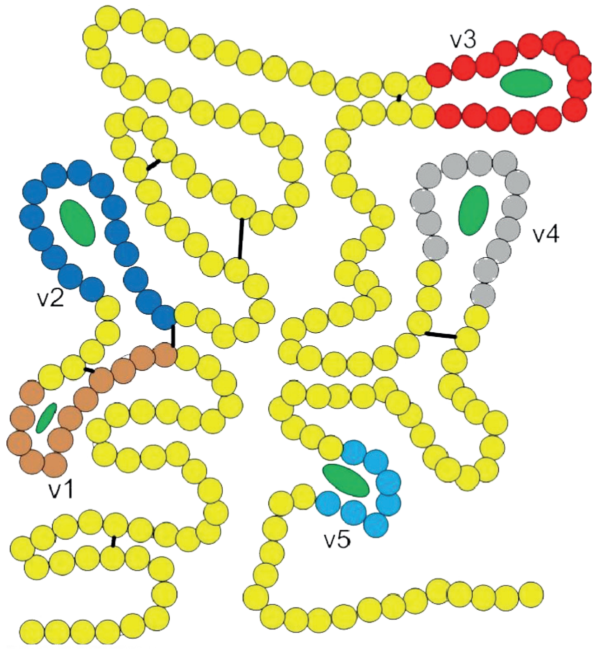
Phase diagram of the extended Ising model on the Shastry-Sutherland lattice

Developed turbulence

Developed turbulence belongs between the last unsolved problems of the classical branch of physics. In this respect, our attention is focused on the theoretical understanding and analysis of universal properties of various turbulent environments as well as processes that take place in them such as turbulent diffusion. Among the most interesting results in this branch of physics obtained recently at the Department of Theoretical Physics belong the calculation of various turbulent Prandtl numbers or the understanding of the influence of various forms of the symmetry breaking on the anomalous scaling of structure and correlation functions of admixture fields at the fundamental level of the corresponding microscopic stochastic models.

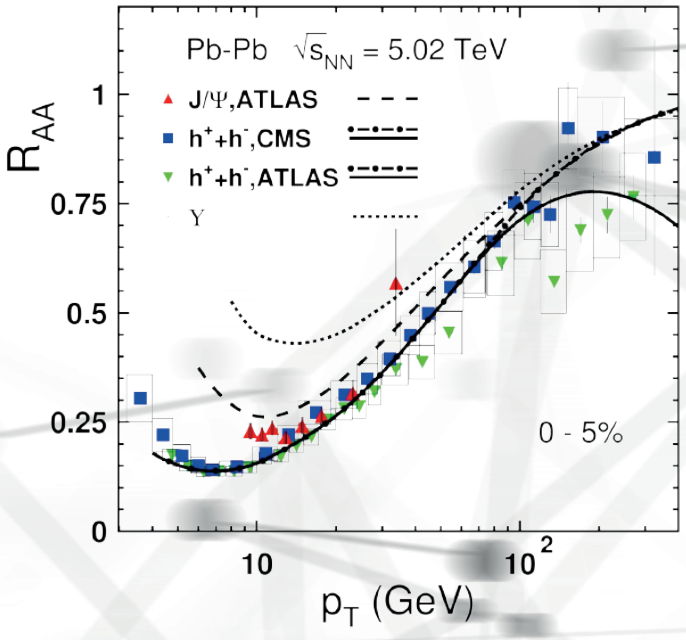
Particle physics

We investigate the onset of various effects which occur in interactions with nuclear targets. We study the manifestation of quantum coherence effects, color transparency, gluon shadowing, Cronin effect, as well as the magnitude of vacuum and medium induced energy loss and effective energy loss caused by multiple initial state interactions of a parton before a hard scattering. Such effects are analyzed in various processes on nuclear targets, namely the inclusive production of light hadrons, direct photons, production of heavy mesons, Drell-Yan process, deep-inelastic scattering off nuclei, coherent and incoherent electroproduction of vector mesons, processes in ultra-peripheral collisions, etc. Model predictions for the nucleus-to-nucleon ratio of production cross sections corresponding to RHIC and LHC kinematical regions are compared with available data.



Interdisciplinary studies

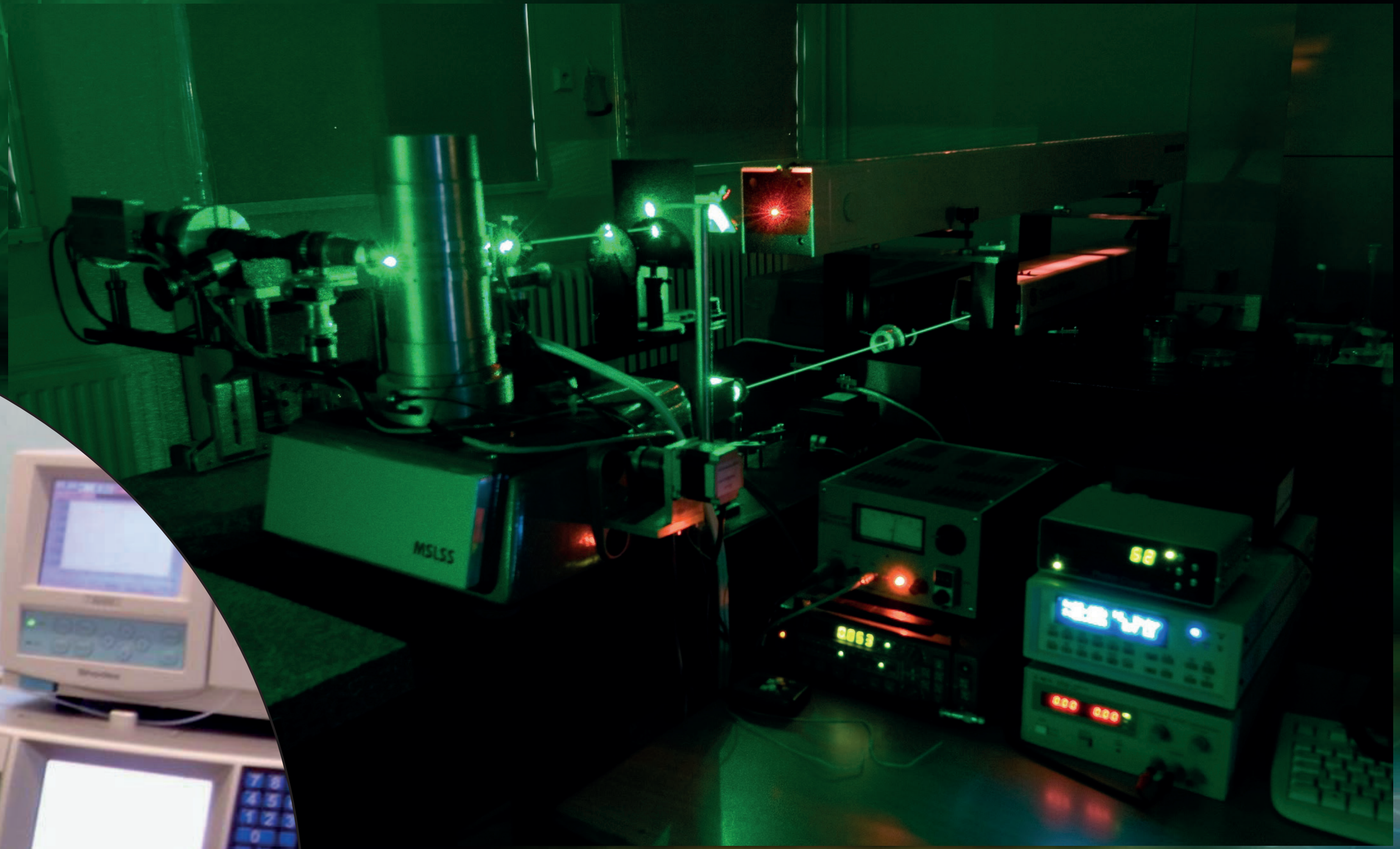
The Department of Theoretical Physics performs also interdisciplinary research with a focus on solving fundamental problems in biology, such as e.g. the mutation of the HIV virus. The genetic variation in the V3 loop obstruction component of gp120 HIV glycoprotein is defined as a solitary standing wave function with the transition state between the interaction of wave function in the DNA and RNA hidden states. It is a parasitism co-state generated from the coupling between two pairs of hidden 8 states of Laurent polynomial in the Chern–Simons current of HIV genotypes. A modified Nahm equation for biology with Lax pairs is defined as the pairs of viral glycoprotein states with the transition between DNA and RNA in the reverse transcription process. We describe and also predict new mutations using a support spinor machine and convolutional neural network based on the imaging technique generated from tensor correlation network.



Theoretical predictions for the universal suppression in production of light hadrons, charmonia and bottomonia with large transverse momenta in heavy ion Pb-Pb collisions are tested by the data from experiments at the LHC.jpg

Department of Experimental Chemical Physics

Chemical physics is a scientific discipline which utilizes physical methods to gain insight into the nature of molecules and their complexes and systems (solutions, mixtures, suspensions, gels, melts, etc.). This encompasses studies on molecules spanning from the smallest water-like molecules to macromolecules (polymers). The chemical physics research area is very close to the concept of soft matter physics. Our department devotes itself mainly to the following research areas: (1) polymers, especially water-soluble polymers and polyelectrolytes; (2) colloidal systems; and (3) self-assembly and phase transitions in complex liquids leading to mesoscale structures, i.e. structures larger



than the molecular scale and smaller than the macroscopic scale. The common denominator of all three areas is the study of various types of interactions involved in these systems. Multiparticle collective interactions cannot be measured directly, and therefore the information on the structure and dynamics of these systems gained experimentally contribute to our knowledge about them. Our department is methodologically focused on detailed macromolecular and nanoparticle characterization based mainly on (but not limited to) scattering techniques. In our opinion, it represents a unique laboratory in Slovakia concerning complex macromolecular and nanoparticle characterization. We utilize several powerful methods that can be used for measurement of accurate nanoparticle size distributions in parallel: ORT (Optimized Regularization Technique) analysis of static light scattering data, NTA (Nanoparticle tracking analysis), AF4 (Asymmetric Flow Field-Flow Fractionation), and Multiangle DLS (dynamic light scattering). Measurements of surface zeta potentials can predict colloidal (in)stability. Unique capabilities concern nanoparticle counting via NTA, measurements of the shape of polydisperse nanoobjects via AF4, measurements of density of unknown nanoobjects via our original commercially unavailable method called Incremental centrifugation coupled with light scattering.

Among the best results achieved in our department we can mention chapters in monographs from renowned publishing houses (Clarendon Oxford, Marcel Dekker New York) focused on using light scattering methods for investigation of ionic polymers (polyelectrolytes). Further remarkable results achieved in our department concern solution behavior of ionic polymers given by an interplay of several types of intermolecular interactions and the issue of formation of mesoscale structures in various liquid systems including dissolved solid compounds, liquid compounds, polymeric compounds as well as gases. In the recent past, we have succeeded in reorienting our long-term basic research also towards applications. We have created and patented a new mechanism for forming polymeric nanoparticles with adjustable size from homopolymers of one type as building blocks. Further patent activities concerned utilization of our knowledge regarding mesoscale structures in complex mixtures towards creating a new original method for screening of hydrophobic contaminants in organic liquids (mainly alcohols and other liquids used in food and pharmaceutical industry) and a new original method for purification of chemical compounds from hydrophobic contaminants (preparation of ultrapure compounds).

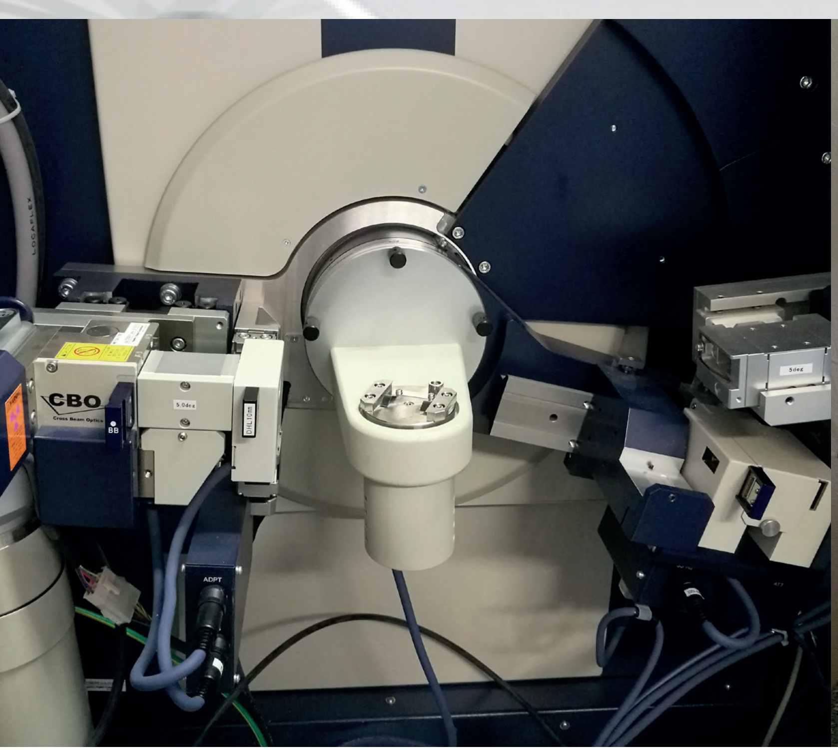
Department of Materials Physics

This Department concentrates on progressive functional materials. The Laboratory´s principal activities are preparing and studying the relationship between the microstructure and superconducting properties of REBCO bulk single-grain superconductors (BSS). In this field the Laboratory has achieved scientific results valued in Slovakia and also abroad, and developed wide international cooperation (ISTEC Tokyo, Argonne National Laboratory, USA, Oxford University, University of Cambridge, IPHT Jena, IFW Dresden, ICMAB Barcelona, CRETA CNRS Grenoble SIT Tokyo, SJTU Shanghai, University of Caen) within multilateral (projects 5RP and 6RP) and bilateral projects. Participation in EU structural funds allowed to build the unique infrastructure necessary for the research and development of progressive materials as X-ray diffraction analyses in a broad temperature range, electron microscopy with micro-analysers (EDS, WDS, EBSD), thermal analysis (DTA, DSC, TG) with mass spectroscopy, technology for preparation of REBCO BSS.

REBCO MMS (REBCO is the abbreviation for the high-temperature superconductor $REBa_2Cu_3O_7$, referred to below as RE123, RE = rare earth element and Y) are suitable for practical applications mainly as superconducting permanent magnets. Part of their unique properties, as a consequence of strong pinning of magnetic flux lines, is their ability to trap one order higher magnetic fields than the best permanent magnets (up to 17 Tesla at 30 K temperature, even 100 times higher energy density), to levitate or suspend stable in a non-homogeneous magnetic field (high levitation force) and to move without friction in a homogeneous magnetic field. The main application possibilities are in the construction of efficient electric rotary machines, magnetic separators, levitation devices such as frictionless bearings, flywheel energy reservoirs, and magnetic levitation transport systems (e.g. MAGLEV trains).

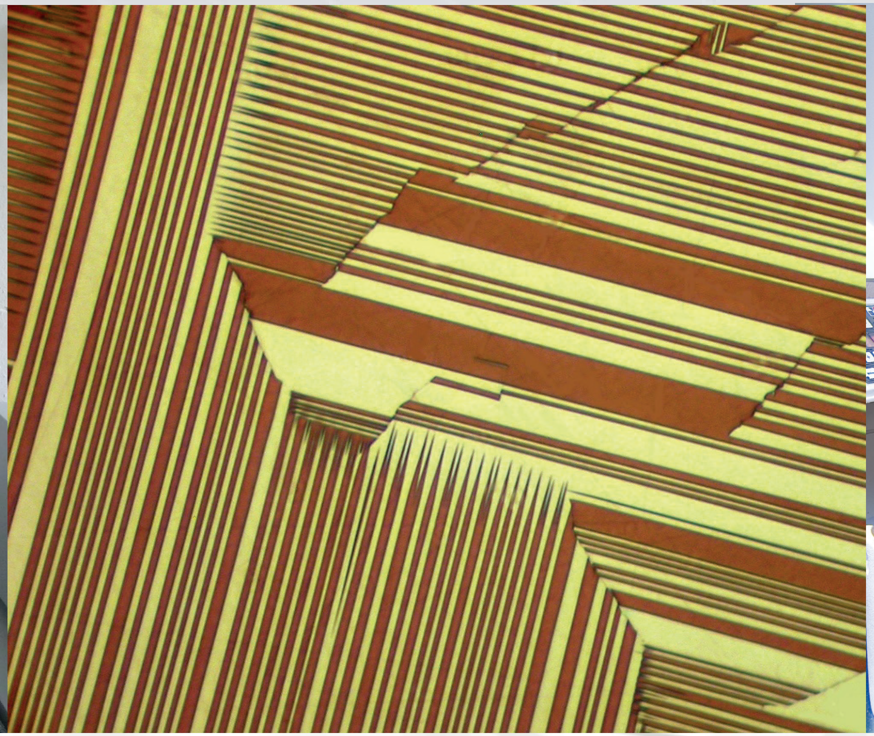
We can ideally imagine YBCO MMS (superconducting magnet) as a cylindrical $YBa_2Cu_3O_7$ single-crystal with a diameter of 30 to 100 mm, in which the pining centres of magnetic flux lines are scattered. These centres may be submicron particles of non-superconducting RE_2BaCuO_5 (211) phase, or the so-called chemical pinning centres: nano-sized areas with a distorted crystal lattice formed by substitute atoms. In this area we cooperate with small company CAN Superconductors.

Besides REBCO BSS we study solidification of rapidly quenched microwires. This research is done in the framework of cooperation with the company RV Magnetics producing microwires for sensors.



X-ray diffractometer RIGAKU for structure characterization.

TG, DTA and DSC thermal analyzer NETZSCH STA.



Twin structure of YBCO single crystal.

Department of Applied Magnetism and Nanomaterials

The Department´s research activities focus on development and characterization of new magnetic materials which can be potentially used in technical practice. The recent research activities are devoted to the new preparation and/or processing techniques that would lead to development of targeted microstructures and desired functional properties. Among the others, we are using unconventional processing techniques such as ultra-rapid annealing and/or thermal treatment in high magnetic fields.

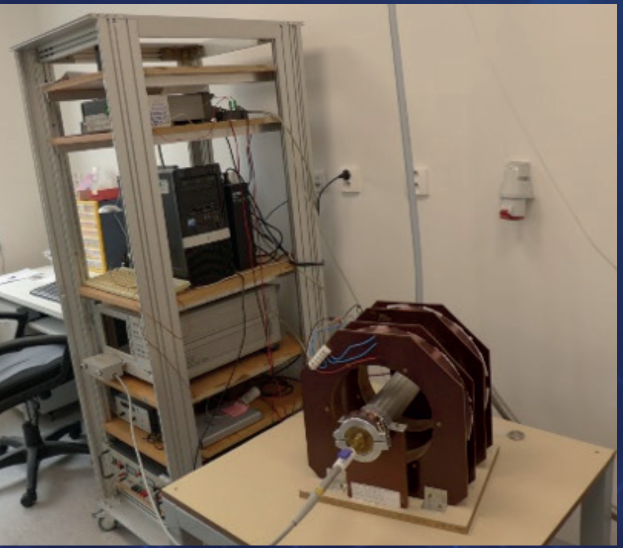
Our long-term interest is focused on Fe-based nanocrystalline alloys prepared by controlled crystallization of amorphous precursors. Besides the high magnetic induction values, these alloys show particularly good soft magnetic properties (high permeability, low values of coercive field and small energy losses). This combination makes them attractive materials for use in several technical applications such as high-frequency transformers, magnetic sensors, various components of telecommunication and electronic devices, or magnetic shielding.

Interesting results have been obtained for rapidly quenched bilayer ribbons prepared by a double-nozzle planar flow casting technique. This preparation method allows parallel formation of two homogeneous amorphous layers (tens micrometers thick) one on top of the other with a mechanically solid interface between them. By using a proper heat treatment, it is possible to transform selected amorphous layers or entire bilayers to the nanocrystalline or microcrystalline structure. Magnetic, magnetoelastic and mechanical interactions between firmly connected layers can be utilized in design of specific sensors for detection and monitoring of bending force, displacement, temperature changes as well as in medical and automotive sector applications.

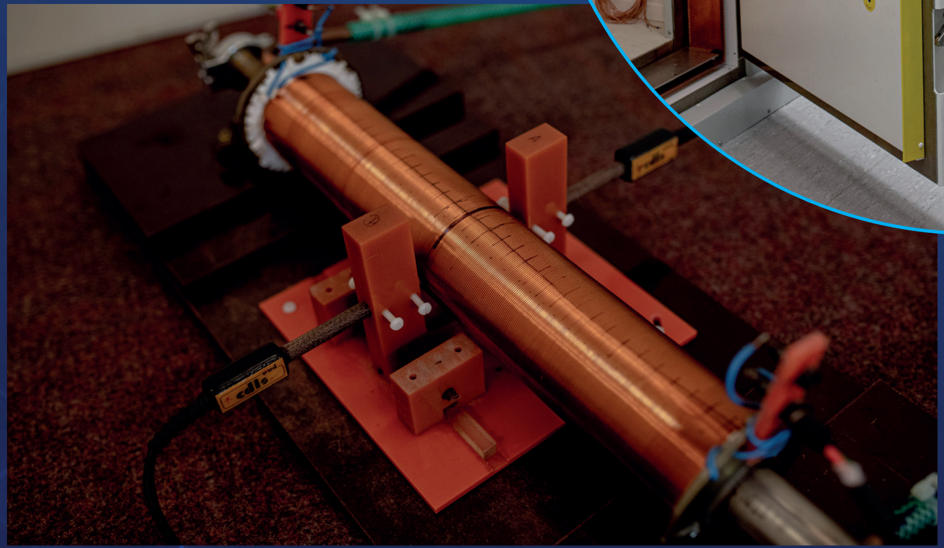
Soft magnetic amorphous and nanocrystalline alloys are objects of our interest also due to their applications in highly sensitive magnetic sensors. Typical examples are flux-gate sensors and GMI sensors based on giant magneto-impedance (GMI) effect. New generation of industrial sensor systems for search and indication of unwanted ferromagnetic objects on belt conveyors have been developed in the close collaboration with Faculty of Aviation, Technical University and EDIS v.d. company in Košice.

Part of the research activities is devoted to development of novel permanent magnets free of critical elements. Optimization of the hard magnetic properties in Mn(Al,Bi) materials was attained through employing the innovative fabrication and processing techniques in addition to the careful compositional tuning.

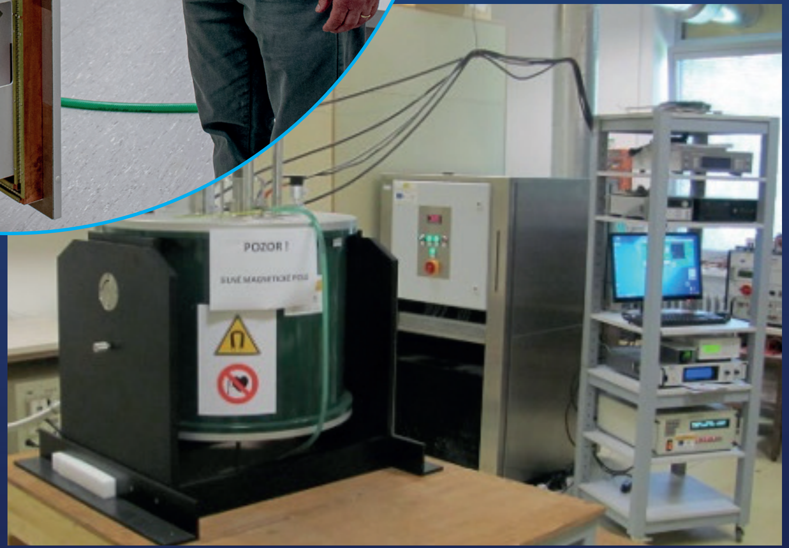
The Department concentrates its attention also on new materials for magnetic refrigeration. This unconventional cooling technology is based on using the magneto-caloric effect occurring under adiabatic conditions. Here the material temperature change is caused by an external magnetic field change. If magnetic material is exposed to an external magnetic field, then the reduction in magnetic spin entropy results in an increase of lattice entropy, which shows itself in rising temperature while demagnetization causes temperature decreases.



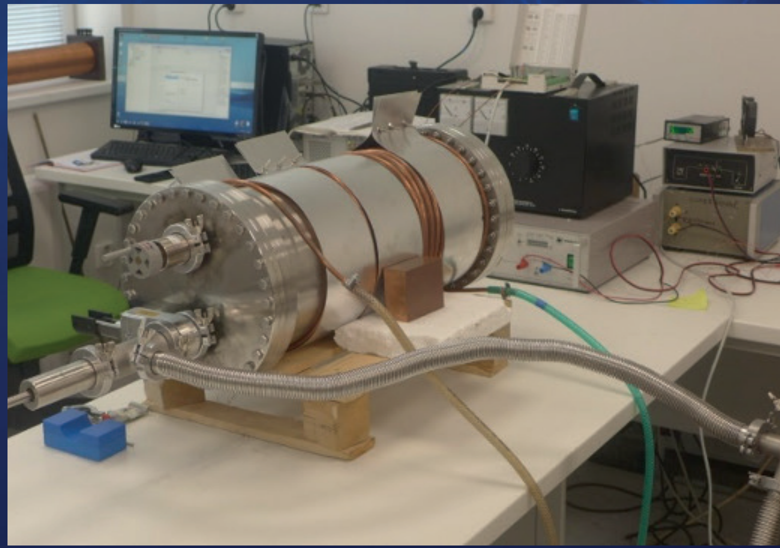
Testing of GMI sensor characteristics



High temperature hysteresis loop tracer in magnetically shielded room



Setup for thermal processing of materials in high magnetic fields



Furnace for rapid annealing

Research Departments at the Institute of Experimental Physics, SAS, Košice:

- Department of Space Physics
- Department of Subnuclear Physics
- Department of Magnetism
- Centre of Low Temperature Physics
- Department of Metal Physics
- Department of Biophysics
- Department of Theoretical Physics
- Department of Experimental Chemical Physics
- Department of Materials Physics
- Department of Applied Magnetism and Nanomaterials

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